CONTRIBUTIONS TO THE PHYSIOLOGY OF THE SPINAL CORD AND ADJACENT PARTS.

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THE nervous system has lately, through the researches of Fritsch, Hitzig and Ferrier, been the subject of much observation and experiment. The path of the conductors of sensation and motion in the spinal cord has been and is still an object about which much discussion exists. Alexander Walker, in 1809, first started the idea that the posterior columns contained the motor conductors, whilst the anterior columns contained the sensory. It was held by Galen, Flourens, Nasse, Longet,* Kürschner, Volkmann and Chauveau that the conductors of voluntary movement and sensibility did not decussate. Brown-Sequard and Budge believed the conductors of voluntary movement did not decussate, but that the conductors of sensory impressions did in part.

Lately, Brown-Sequard explains this sensory decussation in another way. Van Kempen† held that the transmission of voluntary movement in animals is direct in each half of the spinal cord, and that it is partly crossed in the cervical

* Nerven System, Leipzig, 1849.

† Experiences Physiologiques sur la Transmission de la Sensibilité, et du Mouvement dans Moelle Epinëre, Bruxelles, 1859.

region; that the transmission of sensibility in the spinal cord is partly crossed throughout the whole extent of the cord.

Fodera, Cooper, Kölliker and Eigenbrodt* arrived at the conclusion that the conductors of motion and sensation partly decussate. The opposite views were thought to result from the different animals experimented upon, but Von Bezold† proved this to be an error. Schiff‡ arrived at the conclusion that the antero-lateral columns conduct motion and not sensation, and that the gray matter conducts painful sensations, whilst the posterior columns conduct tactile impressions. Ludwig ‖ and his pupils, Miescher, Nawrocki and Dittmar, held that in the rabbit all the sensory and efferent vaso-motor fibres are contained in the lateral columns.

Woroschiloff § was able, by means of a specially devised instrument, to divide the spinal cord in different extents with the least possible injury to the undivided parts. He proved that in the lumbar segment of the cord of the rabbit all the sensory and motor fibres run in the lateral columns. Ott and Smith¶ have, by means of Woroschiloff's instrument, shown that in the cervical segment of the spinal cord the sensory, vaso-motor, motor, cilio-spinal and respiratory nerves run in the lateral columns; that the posterior columns are concerned in coördination, and that the motor and sensory fibres in the cervical segment partly decussate. Ott has shown, by the pupil and bleeding tests, that tactile fibres not only run in the posterior columns, but also in the lateral columns; that inhibitory fibres run in the lateral

* Über die Leitungegesetze im Rückenmarke, Giessen, 1848.

† Untersuchungen aus dem Physiologischen Laboratorium im Würzburg, und über die gekreuzten Wirkungen des Rückenmarkes, Leipzig, 1869,

‡ Lehrbuch die physiologie des Menschen, Jahr, 1859.

‖ Ludwig's Arbeiten. § Ludwig's Arbeiten.

¶ *Am. Med. Journal*, October, 1879.

columns and decussate, and that sweat fibres also run in the lateral columns.

Recently, Schiff has returned to the subject of the spinal cord, holding that the Leipzig School and its followers have been misled by traumatisms; that the antero-lateral columns are unable to transmit any sensory impulses, whilst sensations of pain are conveyed by the gray matter. He used dogs, and permitted them to live for a long time, and after death made sections of the cord, which he examined with a polarizing apparatus.

N. Weiss (*Centralblatt*, 1880, No. 29) has arrived at completely opposite conclusions to those put forth by Schiff. He also used dogs, and made sections at the junction of the lumbar and dorsal segment of the spinal cord. In a young dog the cord was cut so that only the left lateral and left anterior columns were intact, the whole of the gray matter, right half of the cord, and left posterior column being divided. It was found that the dog had sensibility in, and could move, both posterior extremities. The conclusion necessarily followed that one lateral column contains sensory and motor fibres for both halves of the body. If the lateral columns are divided on both sides, then the sensibility and motility is lost behind the section in a complete manner, so that there is no reason to regard the gray matter as conducting, for any distance, either motion or sensation. He holds that the anterior columns do not conduct either sensibility or motion, and confirms completely the experiments of Woroschiloff and those of Ott, that the lateral columns only contain motor and sensory fibres, Ott believing with Schiff that the posterior columns contain tactile fibres. Further, the polarizing tests are, to my mind, by no means so conclusive as those made by microscopic section. Prof. F. Schultze* has made some very

* *Pflüger's Archiv*, Bd. 22.

pertinent experiments with the polarizer, which cause considerable doubt to exist as to the value of this method of investigation. I cannot see what traumatisms have done where I have divided everything except one lateral column, and the animal, a few hours afterward, had sensibility and voluntary movement. There is no need of allowing the animal to live in order to show that the lateral columns conduct motion and sensation. That the traumatisms might not affect other results, I made experiments on animals who lived for a considerable time.

Method.—Kittens were selected, etherized, and the cord bared at the junction of the dorsal and lumbra vetebræ; the skin was divided vertically in the median line, the tissues on each side of the spinous processes of the vertebræ being held away by weighted hooks. The spinous process was denuded by a sharp scraper, and snipped off with a pair of bone forceps. After this, the transverse processes were carefully denuded of their soft tissues, and the vertebræ broken down with a bone forceps and knife, the bones of the kitten being quite soft. The spinal dura mater was now exposed, and divided by a forceps and small knife. The columns of the cord were then divided by a Cooper bistoury. Any hemorrhage following was checked with absorbent cotton. The wound was closed with thread sutures, and the animal allowed to recover and live as long as possible. After its death, the cord was carefully removed, immersed for a short time in alcohol, and then in a weak solution of bichromate of ammonium. After hardening, sections were made, rendered transparent by oil of cloves, and mounted in Canada balsam.

To estimate sensibility, I used the following test: When the animal was pinched and attempted to bite, it was inferred that it had yet sensations of pain. Reflex movements were carefully distinguished from voluntary

movements. To localize the path of the sweat fibres in the lateral columns, I etherized the cat, performed tracheotomy, and laid bare the cord, not in the lumbar region, but in the dorsal above the origin of the sweat-fibres running in the abdominal sympathetic. The cord was then partially divided by means of Woroschiloff's instrument. After waiting about five hours, I divided the medulla oblongata, kept up artificial respiration, and irritated the lower end of the cut medulla with a Du Bois apparatus. The appearance or absence of sweat on the pulps of the posterior extremities was then noted. After death the cords were carefully removed and treated with reagents, in the same manner as has been described. In the cat, the sensory fibres are stated not to decussate, but the appended experiments prove that they do in part.

When I cut everything except one right lateral column, then sensation and voluntary motion were intact.

Kitten Experiment 1, *May* 9, 1880.

Everything cut except one right lateral column, which remained intact.

May 11th.—Has no motion in posterior extremities, but has sensibility.

May 12th.—Has voluntary motion in right posterior extremity, but none in left. Has sensibility in posterior extremities. No anal rhythm.

May 15th.—Begins to use hind legs in walking (right one most). Has sensibility in posterior extremities.

May 18th.—Can support herself while standing on hind extremities as well as fore, also uses them in walking, although she cannot coördinate properly.

May 22d.—Can run as fast, and plays as lively, as any of the uninjured cats, but cannot coördinate as perfectly, one posterior extremity sometimes getting twisted on the other.

May 26th.—Wound nicely healed up. Runs around.

June 4th.—Sensibility and voluntary motion, with loss of coördination.

June 8th.—Died.

Kitten Experiment 2, *May* 20, 1880.

Everything cut except one lateral column.

May 21st.—Sensibility and motion on right side behind the section. Seems to have a good deal of pain. (Cries.)

May 22d.—Tetanic convulsions in morning; in afternoon remained quiet in box, seeming perfectly well and without pain.

May 24th.—Can support herself on hind legs; has a little motion in right hind leg, but more in left. When she walks she pulls or rather drags her posterior limbs after her.

May 27th.—No sensibility or motion in posterior extremities; drags them after her.

May 30th.—Died.

Kitten Experiment 3, *May* 30, 1880.

Everything cut except one lateral column.

May 31st.—Has sensibility, but no voluntary power in posterior extremities.

June 1st.—No sensibility or voluntary power in posterior extremities.

June 7th.—Died.

When I cut the lateral and posterior columns, leaving the anterior and gray matter intact, then no sensibility existed, but voluntary movement ensued.

Kitten Experiment 4, *May* 11, 1880.

Everything cut except anterior columns and gray matter.

May 12th.—No sensibility or voluntary motion in hind extremities.

May 15th.—No sensibility or voluntary motion in posterior extremities.

May 17th.—Has slight voluntary motion in posterior extremities, but cannot use them as a support.

May 18th.—Still has voluntary motion in posterior extremities, which she *moves* in walking or running, but cannot support herself on them. Has no sensibility in posterior extremities.

May 22d.—No sensibility or motion in posterior extremities.

May 28th.—Died.

Kitten Experiment 5, *May 20th.*

Everything cut except anterior columns and adjacent gray matter.

May 21st.—No sensibility or motion of posterior extremities.

May 22d.—Same as May 21st.

May 26th.—Same as above.

May 29th.—Died.

Kitten Experiment 6, *May 20th.*

Everything cut except anterior columns and adjacent gray matter.

May 21st.—No sensibility or motion in posterior extremities.

May 22d.—Same as above.

May 26th.—Slight voluntary power over right hind foot. No sensibility.

Evening.—Died.

Kitten Experiment 7, *June 2d.*

Everything cut except anterior columns and adjacent gray matter.

June 3d.—No sensibility or voluntary motion of posterior extremities.

June 4th.—No sensibility, but has slight voluntary movement in posterior extremities.

June 7th.—Died.

When I divided the gray matter and posterior columns then sensibility and motion were intact.

Kitten Experiment 8, *May 30th.*

Gray matter and posterior columns divided.

May 31st.—Has sensibility in both posterior extremities, and slight voluntary power in right posterior extremity.

June 1st.—Same as above.

June 4th.—No sensibility or voluntary power in posterior extremities.

June 7th.—Died.

Kitten Experiment 9, *June 2d.*

Gray matter cut.

June 3d.—Sensibility in posterior extremities, and slight voluntary movement on the right side posteriorly.

June 4th.—In a collapsed state.

Evening.—Died.

These experiments prove that motor and sensory fibres run in the lateral columns, that the gray matter does not conduct the sensations of pain, and that the sensory fibres in part decussate. In these experiments, after section of everything except the anterior columns and the gray matter, there was in a few cases slight voluntary motion. I do not believe the broken-down gray matter had any part in the conduction of voluntary movement. The two narrow bands adjacent to the anterior commissure of the cord are the transmitters of voluntary movement. It is evident that trauma has prevented this phenomenon from taking place in the late experiments upon this subject. The section of the inhibitory fibres in both lateral columns would explain the usual absence of voluntary movements by the anterior columns in some experiments. The inhibitory fibres being irritated depress the action of the spinal ganglia beneath, so that they do not respond to the voluntary impulses coming from above. These observations are also in accord with evidence derived from pathology, as in "descending degeneration," after an old hemiplegia, there, the fibres are degenerated in the crossed and direct pyramidal tracts. The observations of Flechsig on embryos also substantiate these observations, comparative anatomy, pathology and physiology being in complete agreement upon this question. According to the researches of Dr. Ott and myself, the following table explains the conclusions upon the physiology of the spinal cord:

Posterior columns conduct in part tactile impressions and coördination impulses.

Lateral columns conduct vaso-motor impulses, voluntary motion, sensations of pain and partly tactile sensibility; the inner half of the middle third of the lateral columns contain mainly the inhibitory and sudorific nerves, the sudorific nerves running mainly anterior to the inhibitory.

Anterior columns conduct voluntary motion in part.
Gray matter does not directly conduct any of the above-named impressions.

That the tactile fibres cannot be demonstrated in the posterior columns except after bleeding, does not prove that they are pathological phenomena. I believe the relations of the phenomena are explained as follows: When all the spinal cord is divided except the posterior columns, all the inhibitory fibres have been irritated which inhibit the transmission of sensations below the section, whilst the irritation of the sensory nerves by the section calls into activity the monarchical inhibitory centres in the crura and thalami, which restrain the passage of sensations above the section. Now bleeding produces a state of hyperæsthesia, either by paralysis of the inhibitory ganglia or by an excitation of the spinal sensory ganglia. That inhibition is overcome in the central nervous system in some manner is shown by the rhythm of the sphincters after bleeding. In experiments on the functions of the posterior columns, the bleeding in some way antagonizes the inhibitions, and tactile impressions are readily conducted to the brain, and the animal moves when touched.

THE PATH OF THE SWEAT-FIBRES.

It has already been shown by Dr. Ott* that these fibres run in the lateral columns. My object has been to determine more accurately in what part of the lateral columns they run. The sections of the cord were made with Woroschiloff's instrument. I divided both lateral columns, and then, after waiting some hours, I irritated the medulla, but no sweat appeared upon the posterior extremities. The animals used were cats, and artificial respiration was kept up during the irritation of the medulla. When I divided

* *Journal of Physiology*, vol. ii, No. 2.

the cord as in fig. 1, then sweat appeared upon the right posterior extremity, but not upon the left. When the cord was divided as in fig. 4, everthing being cut except the

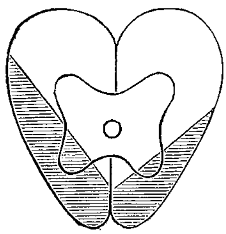
FIG. 1.

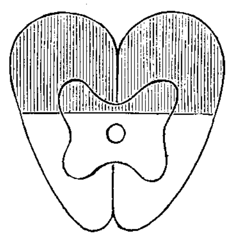
FIG. 2.

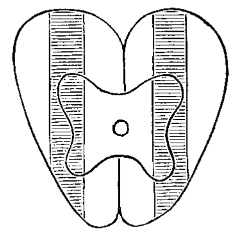
FIG. 3.

left anterior column and the anterior third of the left lateral column, then, upon medullary irritation, no sweat appeared upon the posterior extremities. If the cord was divided as in fig. 3, then no sweat appeared upon the posterior extremities after irritation of medulla. These experiments show that the sweat-fibres run mainly in the inner half of the lateral columns. If the cord is divided as in fig. 2, then sweating appeared. If the cord was divided as in fig. 5, then sweating appeared more on the right side than upon the left. It is evident that the cut, in this experiment, on the left side of the cord struck the main body of the sweat-fibres. The above experiments prove

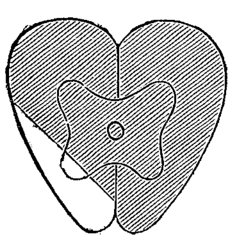
FIG. 4.

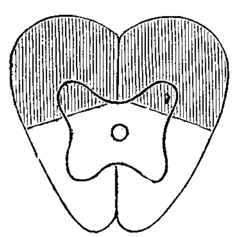
FIG. 5.

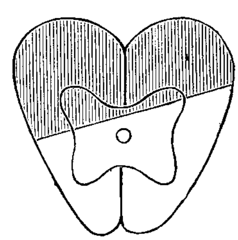
FIG. 6.

that the sweat-fibres run mainly in the inner half of the middle third of the lateral columns. When the spinal cord was divided as in fig. 6, and the medulla irritated, sweat-

ing ensued in both posterior extremities, more so on the right side than upon the left, the lateral columns of the right side being not so deeply divided. In this experiment the rhythm of the sphincters was present, showing that the sweat-fibres mainly run anterior to the inhibitory.

ACTION OF DRUGS ON THE SWEAT CENTRES.

The effect of drugs on the sweat centres is a subject which is yet to be worked out in the main. A few drugs have been worked out by Luchsinger, Nawrocki, Ott and myself. Ott has shown that after a sweat-fibre in the sciatic has degenerated and its irritation by faradic current produces no effect, the use of muscarin still called out sweat in that foot. The following drugs, bromide of ethyl, piscidia erythrina, aconitia and lobelia, have been investigated. My method of procedure was as follows: Cats were selected, the sciatic divided, and the drug given either subcutaneously or by the jugular; then the posterior extremities were watched as to their sweat secretion. Artificial respiration was kept up lest an excess of carbonic anhydride would stimulate the sweat centres and confuse the result. I shall give here only a few of the many experiments made with different drugs.

Bromide of Ethyl.

This new anæsthetic causes sweating, and it was desired to determine if it was due to a central or peripheral stimulation.

Experiment, kitten.—Left sciatic was divided, then it was ethylized, and it was found that no sweating appeared in the left posterior extremity, while sweating, to a considerable degree, did take place in all the others. Artificial respiration was kept up to eliminate an excess of carbonic anhydride. This experiment proves that bromide of ethyl

mainly excites sweat by a stimulant action on the sweat centres located in the spinal cord.

Piscidia Erythrina.

This new narcotic was tested as follows:

Experiment, kitten.—Left sciatic divided, subcutaneous injection of half teaspoonful fluid extract piscidia erythrina. All the extremities sweat except the one whose sciatic is divided.

This shows that piscidia erythrina acts partly by a central stimulation.

Aconitia.

Experiment, kitten.—Left posterior extremity has its sciatic divided.

1.40 P.M.—Subcutaneous injection ¼ grain aconitia in water.

1.55 P.M.—Subcutaneous injection ¼ grain aconitia in water.

2.09 P.M.—Cries and bites.

2.15 P.M.—Subcutaneous injection ¼ grain aconitia in water.

2.20 P.M.—Profuse salivation.

2.28 P.M.—Sweating in all extremities except the one whose sciatic is divided.

2.40 P.M.—Tracheotomy performed, and artificial respiration was resorted to, proving that aconitia acts by an excitant action of the sweat centres.

2.48 P.M.—Atropia solution administered subcutaneously caused the feet to become dry.

Lobelina.

Experiment, kitten, at 12 M.—One sciatic divided, and one drop of the acetate of lobelina (in water) injected into the central end of the carotid, toward the brain. Sweating occurred in all the extremities except the one in which the sciatic was divided.

12.22 P.M.—Another injection of acetate of lobelina given subcutaneously.

12.28 P.M.—Sweating ensued in all the extremities.

This experiment proves that lobelina can excite sweating by a peripheral action.

The following experiment was then performed:

Experiment, kitten.—Left sciatic divided and left to degenerate. One week after section of this nerve the peripheral end was irritated by the induction current of a Du Bois apparatus, which produced no sweating in the attached foot.

1.20 P.M.—Fluid extract lobelina given subcutaneously. Profuse sweating occurred in all extremities except the one whose sciatic had been divided.

1.25 P.M.—Second injection fluid extract lobelina with same result.

2.20 P.M.—Third injection fluid extract lobelina.

2.30 P.M.—Sweats in all extremities.

This experiment proves that lobelina can excite sweating in a foot whose sciatic has degenerated. Ott has already proved that muscarin acts in a similar manner.

Veratrum Viride.

Expt., kitten.—Left sciatic divided, tracheotomy performed and artificial respiration kept up; one fluid drachm of fld. ext. veratrum viride was then administered subcutaneously. Sweating ensued in all the extremities except the one with sciatic cut. This experiment proves that veratrum viride mainly excites sweating by a central action.

PONTAL CONVULSIONS.—THEIR INHIBITION.

It has already been shown by Nothnagel that injections of chromic acid into the medulla and pons excited convulsions of an epileptiform character. In a cat, I injected a

few drops of chromic acid into the pons at the junction of the medulla oblongata, after which convulsions of the posterior extremities commenced. They began slowly, reached a maximum, and then decreased. Their number was about 120-140 per minute, alternating in each posterior extremity, then becoming quiet for a short time.

Fig. 7 (see opposite page) gives a graphic record of the convulsive movements. They were made by attaching a posterior extremity to a Marey's myograph registering on a drum of a Marey-Secretan apparatus. While these convulsions were going on, I discovered a means of arresting them, which has hitherto remained unnoticed. I found that by pinching the ear of the cat the convulsions decreased and were arrested.

INFLUENCE OF AN IRRITANT INJECTION IN DIFFERENT PARTS OF THE BRAIN ON THE MOVEMENTS AND SECRETIONS.

1. An injection of chromic acid about the left middle cerebellar crus determined movements of rotation about the long axis of the animal, from the side of the lesion toward the uninjured side.

2. An injection of chromic acid into the right thalamus and right side of the corpus callosum caused dilatation of the pupils, straddling movements of the posterior extremities; cries considerably; diagonal sweating, that is, the right fore paw and left hind paw sweat the most.

3. An injection of chromic acid into the left side of the pons at its junction with the medulla caused the head to turn to the right and upward; the animal lost all coördination; posterior extremities have alternate epileptiform convulsions, anterior extremities relaxed; places hind feet in rear of head; pupils contracted.

4. An injection of chromic acid into both optic thalami and right side of nates caused straddling movement of the

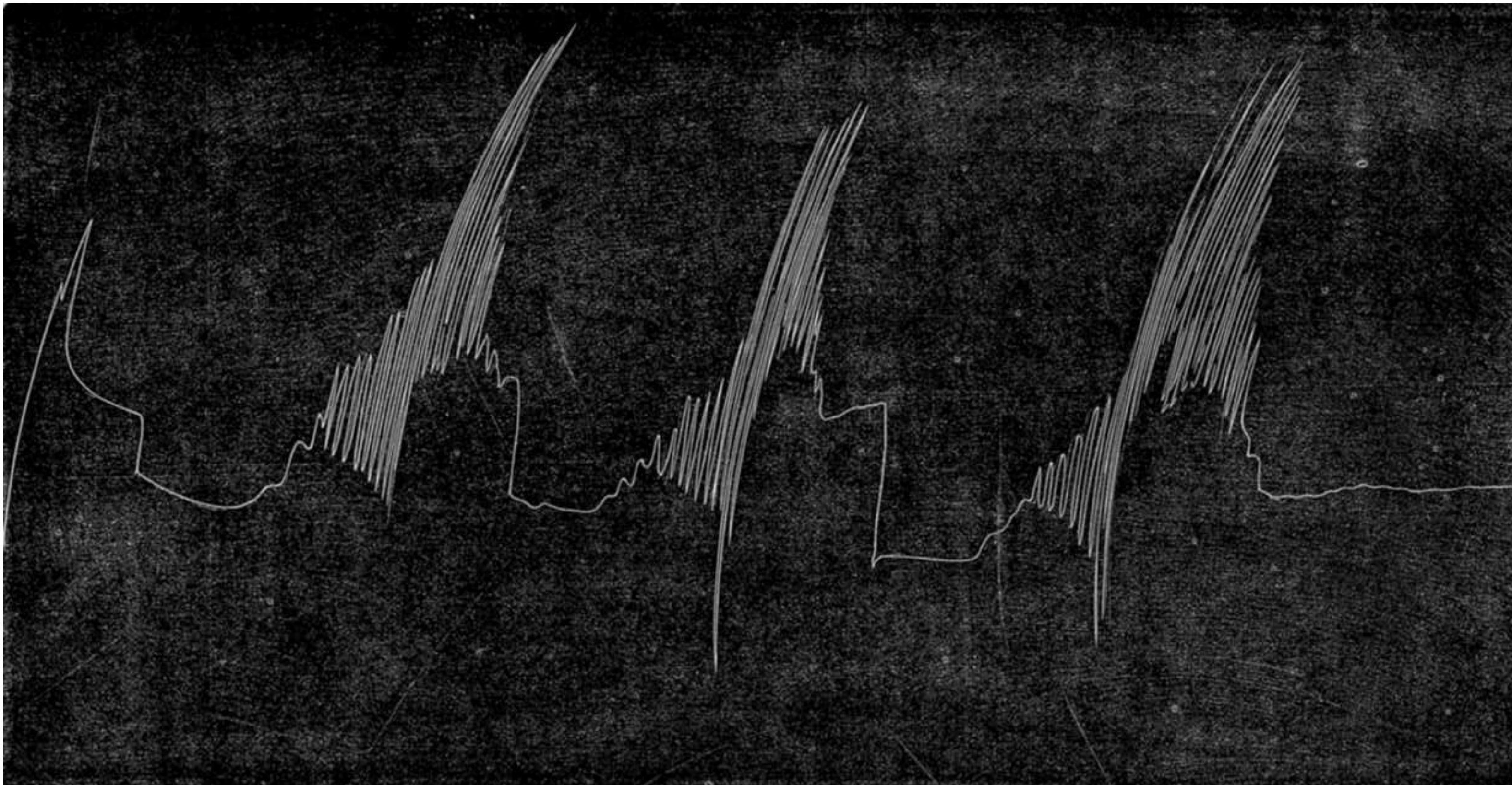

FIG. 7.

posterior extremities, want of coördination, rhythmical movements of left posterior extremity; pupils dilated; goes to left in progression; rhythm of sphincter ani; seems blind; cries during a considerable part of the time; trembling of whole body; when walking raises posterior extremities nearly to body; body twisted to right; raises hind feet into the air, and walks on anterior extremities.

5. An injection of chromic acid into the right and left corpora striata had no effect.

6. An injection of chromic acid into the right optic thalamus and right natis and testis caused the animal to roll from right to left; extension of the left forepaw; head twisted to the right. No difference in sweat secretion.

7. An injection of chromic acid into the middle of the right optic thalamus and part of left caused paralysis of the left posterior extremity; moves toward left; sweats most on left side. Can't coördinate.

8. An injection of chromic acid into the right lobe of the cerebellum and posterior surface of right natis, the animal goes to the right; the feet are dry; rhythm of sphincter ani preserved; pupils dilated; convulsive movements of anterior extremities.

9. An injection of chromic acid into the right cerebellar peduncle, the right side of pons and cerebellum, then profuse sweating ensued. Oscillation of eyeballs, and rapid breathing.

10. An injection of chromic acid causing a lesion of the right natis and testis and right lobe of cerebellum; the right pupil was dilated, the left contracted; tonic retraction of the head; mouth thrown to the left; tonic extension of the anterior extremities; moves to the left; anterior extremities stiff; feet dry.

11. An injection of chromic acid into the middle lobe of the cerebellum down to the pons Varolii, then retrograde

movements ensue; falls to either side; both pupils contracted; feet moist.

12. An injection of chromic acid into the corpora quadrigemina, anterior surface of cerebellum, and optic thalamus superficially, expirations are inhibited. Makes frequent inspirations.

13. An injection of chromic acid into the iter a tertio ad quartum ventriculum causes the animal to fall on either side. No expiration; jerking inspiration; pupils dilated; no rhythm; feet dry.

14. An injection of chromic acid into the right optic thalamus and right corpora striata causes a dilatation of the pupils; no coördination or voluntary movement; sweating normal.

15. An injection of chromic acid into the cerebellum and right side of the corpora quadrigemina causes the animal to go to the right; pupils normal; want of coördination; feet nearly dry; no anal rhythm.

Appended are the experiments upon which the above observations are based:

Cat Experiment 1, *May* 20, 1879 (4 P. M.).

Two drops of a one-per-cent. solution of chromic acid administered on right side of the head, below and back of the ear.

Symptoms.—Tendency to go from left to right; cannot walk; lies on belly; feet extended. Defecation taken place. Extension of right paw. Voluntary movements over right fore paw and right hind paw. Circular movement of whole axis from left to right. Sensation perfect in both posterior extremities. Right hind paw sweats more than left. Left fore paw sweats most.

4.30 P. M.—Profuse salivation; commencing to get voluntary power over all extremities, especially on right side and in right fore paw.

5.30 P. M.—Animal lies in stupid state, but on pinching tail, arouses and cries.

May 21st.—Has better use of right extremities than yesterday. No change in color of feet (vaso motor). Can move left extremi-

ties, but has not the power in them to raise herself. Right hind paw and left fore paw sweat more than the other extremities. Seems to be conscious the entire time.

In cage, lies still if left to itself, but tries to walk out of the way when handled. When out of cage, tries its best to walk, even if not touched, and drags itself along by means of its right fore and hind paws. Nurses a little.

May 22d.—Remains perfectly conscious; tries to walk, pulling itself along by means of its right extremities; nurses well; sweating remains same as before, although not in such a marked degree.

May 23d.—Better use of right extremities than before, and improving generally.

May 24th.—Symptoms the same.

May 25th.—Symptoms the same.

May 26th.—Feet do not sweat more than normal; seems perfectly well (with the exception of the paralysis). Other symptoms the same.

May 27th.—Symptoms the same.

May 28th.—*Post-mortem:* Lesions in left lobe of cerebellum, near left cerebellar crus, just behind left nates.

Cat Experiment 2, *May* 23, 1879.

Two drops of a one-per-cent. solution of chromic acid injected into brain.

Symptoms.—Cat immediately walks, spreading her hind legs wide apart; lies down and cries; makes no attempt to get up; lies in a stupor; when aroused and stood on its feet, cries very loudly for a moment or two, and then passes into the stupor again. Makes no attempt to walk when stood on feet; does not seem perfectly conscious of where it is, but only of pain (when aroused). Erector muscles of limbs seem perfectly paralyzed; cries continually; pupils dilated; sphincter ani partially relaxed.

May 24th.—Symptoms the same.

May 25th.—Symptoms the same; still cries.

May 26th.—Seems perfectly well; cries a little; otherwise same as above.

May 27th, 10.25 A.M.—Injection of 10 minims fluid extract jaborandi in right flank. Salivation commencing. Pupils dilated. Feet sweat profusely. Right fore paw and left hind one sweat the most. Both hind paws spread out when standing or walking.

June 13th.—Second injection of chromic acid.

Second injection into the pons.

Symptoms.—Animal lost all coördination. Head turned to right and upward. Turns body to right.

Agitation of posterior extremities. *Convulsive attack.* Fore extremities relaxed and motionless during the convulsive attack of hind extremities. Places hind paws on back of neck. The convulsive movements begin slowly, reach a maximum, and then decrease. They are about 120–140 per minute. Posterior extremities alternate, then they become quiet for a short time, and again commence. Pinching the ear on the side where the convulsive movements take place, arrests them. Hyperæsthesia of posterior extremities. No sweating. Feet dry. No rhythm. Color of feet pale. Pupils at first very much contracted.

Post-mortem.—Injury to right corpus callosum, and superficial lesion on the inner side of right optic thalamus, from first experiment.

Result of 2d Experiment.—Lesion in upper part of medulla oblongata, on left side of floor of fourth ventricle.

Cat Experiment 3.

May 23d.—Injection of a one-per-cent. solution of chromic acid in the back part of head.

Symptoms.—Spreading of hind legs. Stands perfectly still. Want of coördination. Rhythmical movement of left hind leg. Tendency to go from right to left. Pupils dilated. Rhythmical movements of sphincter ani. Lies in a continued stupor. Does not cry when tail is pinched, but kicks. Produces a weak cry when tail is trodden on by the foot.

May 24th.—Seems to be blind; goes around in a circle from left to right, crying all the time. Stops a short time, and then goes around again. Shakes constantly, over her entire body. When she went around in a circle she spread out and lifted up her hind legs curiously (legs raised nearly to body). Goes in a corner by herself and sits down. These sittings seem to be periods of stupor, which when aroused from, she immediately goes around in a circle again, as described before. Whole body twisted toward right. Raises left hind paw when she bends to right side. Incoordination in posterior extremities. Pupils dilated. Goes around in a circle from left to right, throwing (as she walks) both posterior extremities in the air. After each period of rest succeeding the circle movement, the whole body is turned toward the right. Walks on front paws.

May 25th.—Symptoms about the same.

May 26th.—Goes around in a circle from left to right; cries; back legs spread a little apart when walking. Runs quite lively. Does not seem to suffer any. Pupils dilated.

May 27th.—Drags herself around. Seems to be entirely free from pain. Continues to go in a circle from left to right. Otherwise progressing.

May 28th.—*Post-mortem:* Superficial lesion of right and left optic thalami and right natis.

Cat Experiment 4, *July* 10, 1879.

Injection into the brain of the one-per-cent. solution of chromic acid. This first injection had no effect, and consequently a second injection was given.

Symptoms.—Rolls from left to right immediately after injection. Extension of left paw; periods of rest, and then rolls again. Head twisted toward right. Lies still, with head twisted as just stated. On side, unable to rise. No difference in sweat secretion.

Post-mortem.—Superficial lesion of right and left corpora striata. Deep lesion of right optic thalamus, and right natis and testis. The remaining parts intact. First injection involved corpora striata. No effect. Crura cerebri intact.

Cat Experiment 5.

July 15th.—Injection of one-per-cent. solution chromic acid.

Symptoms.—Left posterior extremity paralyzed; can't coördinate; moves to the left; paralyzed on whole left side; sweats most on left side. No rhythm. No difference in pupils.

July 16th.—Symptoms the same.

Post-mortem.—Lesion of right optic thalamus in its middle, and part of left optic thalamus.

Cat Experiment 6.

July 13th.—Injection of a *concentrated* solution chromic acid.

Symptoms.—Goes from left to right. Defecation taken place. Feet dry. Rhythm of both sphincters. Pupils widely dilated. (Right eyeball projects more than left?) Convulsive movements of anterior extremities. Urinates.

July 14th.—Very slight rhythm of sphincters. Sweats more than before, although fore feet are rather dry.

Post-mortem.—Deep lesion of right lobe of cerebellum, extending to posterior surface of right natis.

Cat Experiment 7.

July 13th,—Injection concentrated solution chromic acid.

Symptoms.—Rapid breathing. Profuse salivation. Oscillation of eyeballs; defecation taken place. Cries on pinching tail. The nystagmus disappeared on next day. Sweating normal. No rhythm at any time.

Post-mortem.—Deep lesion just in front of right cerebellar peduncle, involving right side of pons and cerebellum.

Cat Experiment 8.

July 13th.—Injection of a concentrated solution of chromic acid on right side of head.

Symptoms.—Right pupil dilated, and left contracted. Defecation taken place. Tonic retraction of head with mouth thrown to left. Tonic extension of fore feet. Moves to left. Retraction great enough to support the body; head still retracted; does not cry. Feet dry; 3d day, feet still dry.

Post-mortem.—Lesion involving nates, especially the right, and the posterior surface of testes, especially the right, and the right lobe of cerebellum.

Cat Experiment 9, July 13, 1879.

Injection of a concentrated solution chromic acid.

Symptoms.—Backward movement. Falls to either side. Defecation taken place. Both pupils contracted. On least irritation, moves fore paws normally. Feet moist. Died next day.

Post-mortem.—Lesion, middle lobe of cerebellum to pons Varolii, not involving it.

Cat Experiment 10.

July 13th.—Injection of concentrated solution chromic acid on right side of head behind right ear.

Symptoms.—Feet were moist before the injection, but afterward they almost immediately became dry. The breathing is inhibited in expiration. A cat makes frequent inspirations but no marked expirations. When the tail is slightly pinched, or even touched, the animal makes marked movements with the posterior extremities. Death took place half an hour after the injection.

Post-mortem.—Superficial portion of corpora quadrigemina mainly the seat of lesion. Anterior surface of cerebellum superficially involved. The optic thalami very superficially and slightly stained by the injection.

Cat Experiment 11.

July 15th.—Injection of concentrated solution chromic acid.

Symptoms.—Falls to left on walking ; sits still and rolls on left side ; lies on right side ; walks, falling to right and left. Cries when tail is pinched. Feet dry. Jerking inspiration ; no expiration. Pupils slightly dilated. No sphincter rhythm.

Post-mortem.—Lesion along the length of the iter a tertio ad quartum ventriculum.

Cat Experiment 12.

July 18th.—Injection of concentrated solution chromic acid.

Symptoms.—Pupils dilated ; hardly any sensibility in tail or posterior extremities. No coördination or voluntary movement. No rhythm. Sweating normal.

Post-mortem.—Lesion of left optic thalamus mainly, and a greater portion of the corpora quadrigemina on the right side.

Cat Experiment 13.

July 18th.—Injection of concentrated solution chromic acid just behind external occipital protuberance.

Symptoms.—Goes from left to right ; pupils normal ; runs around continually in a circle ; sits still, with head turned to right ; cannot stand, but still continues to go from left to right by dragging herself. Lies still on rigth side ; struggles to drag herself to the right, but cannot. Lies still, with head turned to right. Want of coördination.

July 19th.—Head still turned to right. On pinching tail, cries and goes around in a circle. Feet nearly dry. No rhythm at any time.

Post-mortem.—Lesion, upper and anterior portion of cerebellum, and right corpora quadrigemina.